CHALLENGES IN NEAR NAVIGATION

**B. G. Williams, J. K. Miller, P. G. Antreasian,
C. E. Helfrich, W. M. Owen, D. K. Yeomans**

**Jet Propulsion Laboratory,
California Institute of Technology,
Pasadena, CA**

The Near Earth Asteroid Rendezvous (NEAR) Discovery mission is the first to send a spacecraft to rendezvous with and orbit about an asteroid. Launched in February 1996, the interplanetary trajectory of the NEAR spacecraft included a targeted flyby of the asteroid 253 Mathilde in June 1997 and used an Earth gravity assist in January 1998 to enable this low-cost mission. The spacecraft is currently on course for insertion into orbit about the asteroid 433 Eros in February 2000. The navigation for the cruise phase of the mission, even with its stringent requirements, is routine by comparison to the orbit phase of the mission. The navigation challenge for the orbit phase is to devise an adaptive orbit scenario that accounts for the crudely known asteroid physical parameters while maintaining required navigation accuracy. Improving the estimates of Eros' physical parameters such as spin state, shape and gravity potential of Eros, as the spacecraft approaches and is inserted into orbit about the asteroid is critical to mission success. Unlike a planetary orbiter, the very low gravity of the asteroid means that the spacecraft can easily escape Eros or crash into its surface with very little change in velocity. This places additional demand on navigation accuracy while also imposing a generally shorter response time than that usual for planetary orbit missions. This presentation details the response of the NEAR navigation team to these challenges in terms of design and execution of the orbit phase navigation. The approach chosen uses both DSN radio metric Doppler and range data and optical landmark tracking data for the normal estimation process. In addition, laser altimeter range is included in the navigation estimates whenever the spacecraft altitude is between about 30 km and 100 km.

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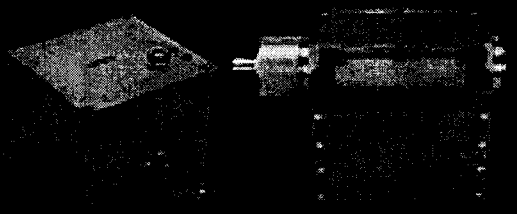
California Institute of Technology
Pasadena, CA 91109


Near Earth
Asteroid Rendezvous

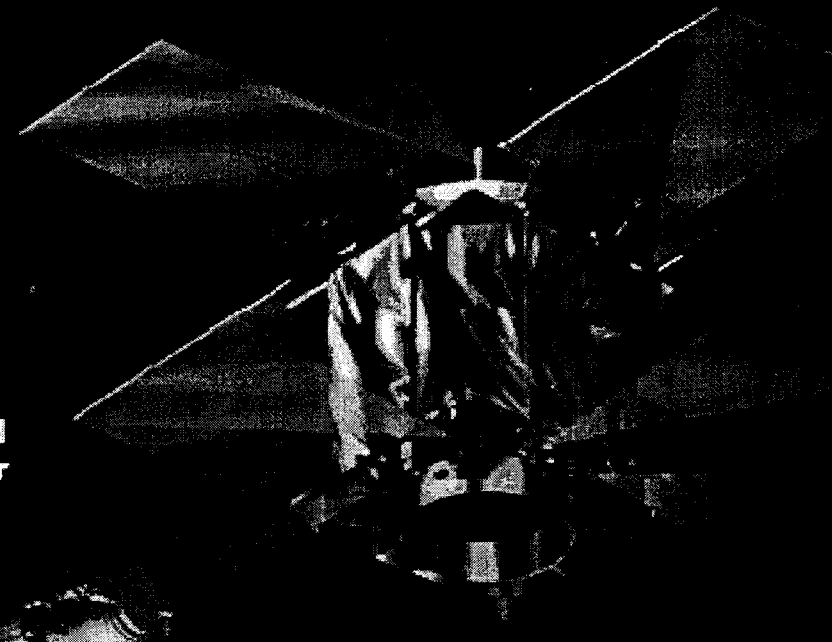
NEAR SCIENCE PAYLOAD

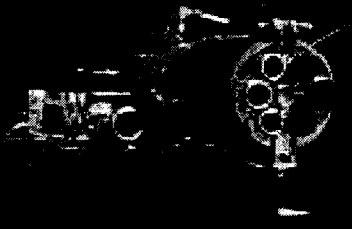
Magnetometer



X-ray
Solar Monitor Sensors

Near-Infrared
Spectrometer



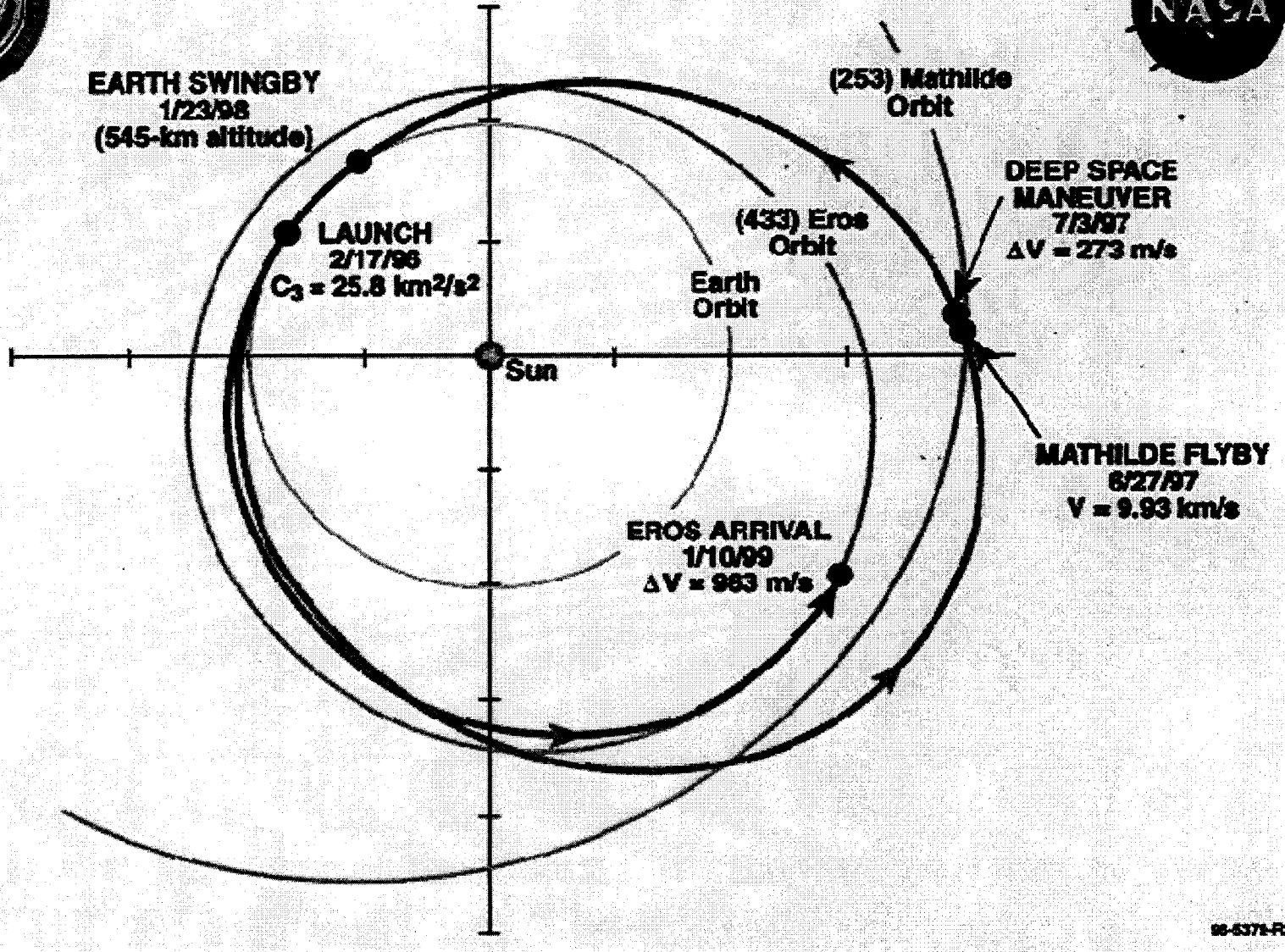


Laser Altimeter

Multispectral
Imager

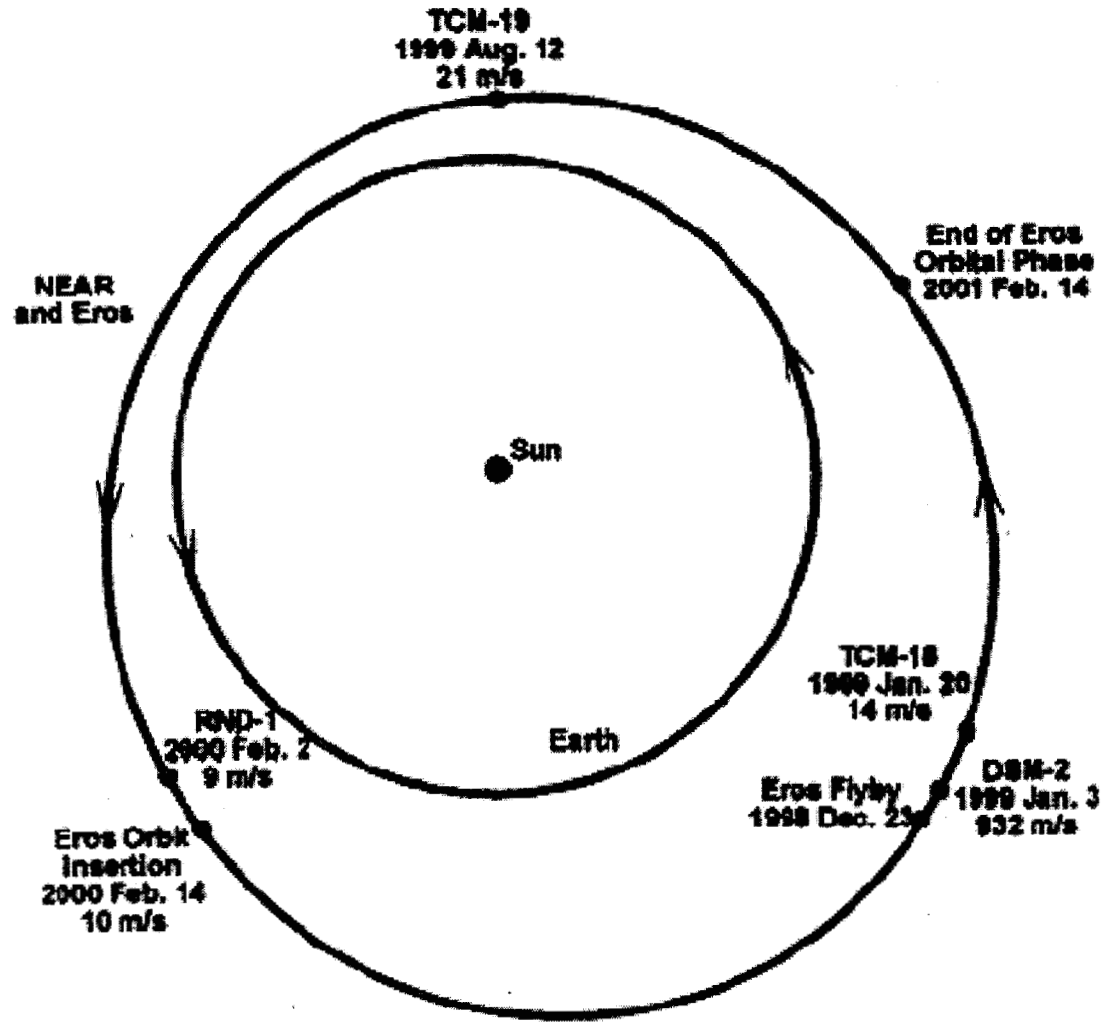
X-ray/Gamma-ray
Spectrometer

NEAR Trajectory Profile



Near Earth Asteroid Rendezvous

Heliocentric Orbits of NEAR and Eros



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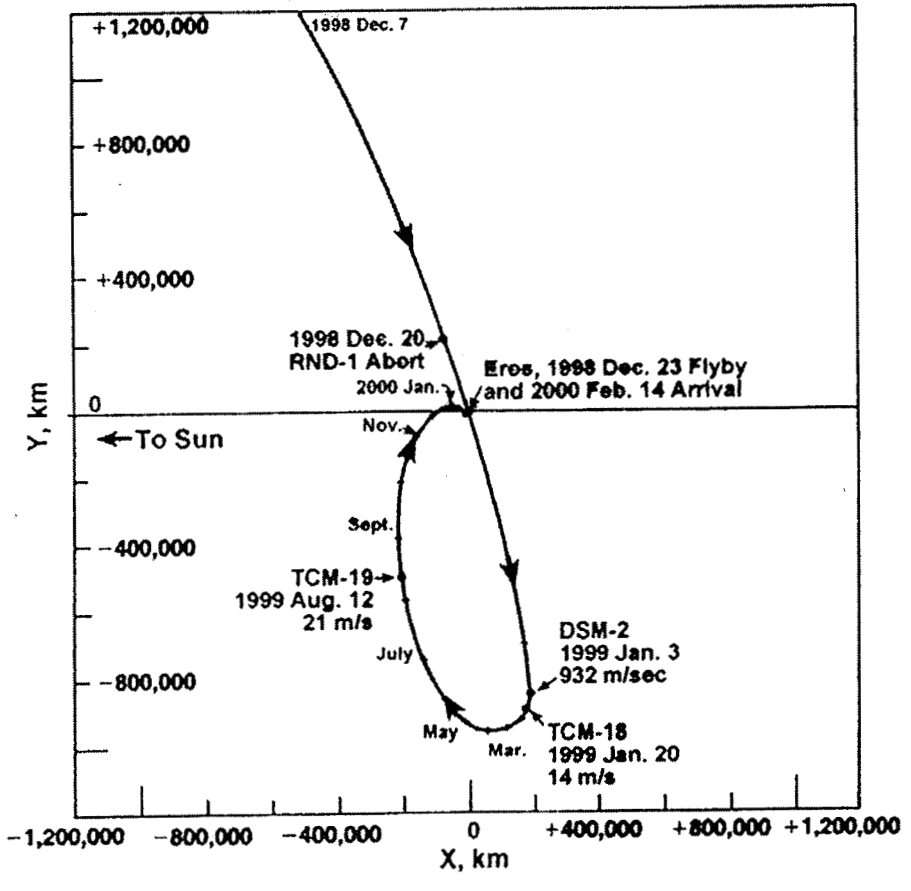
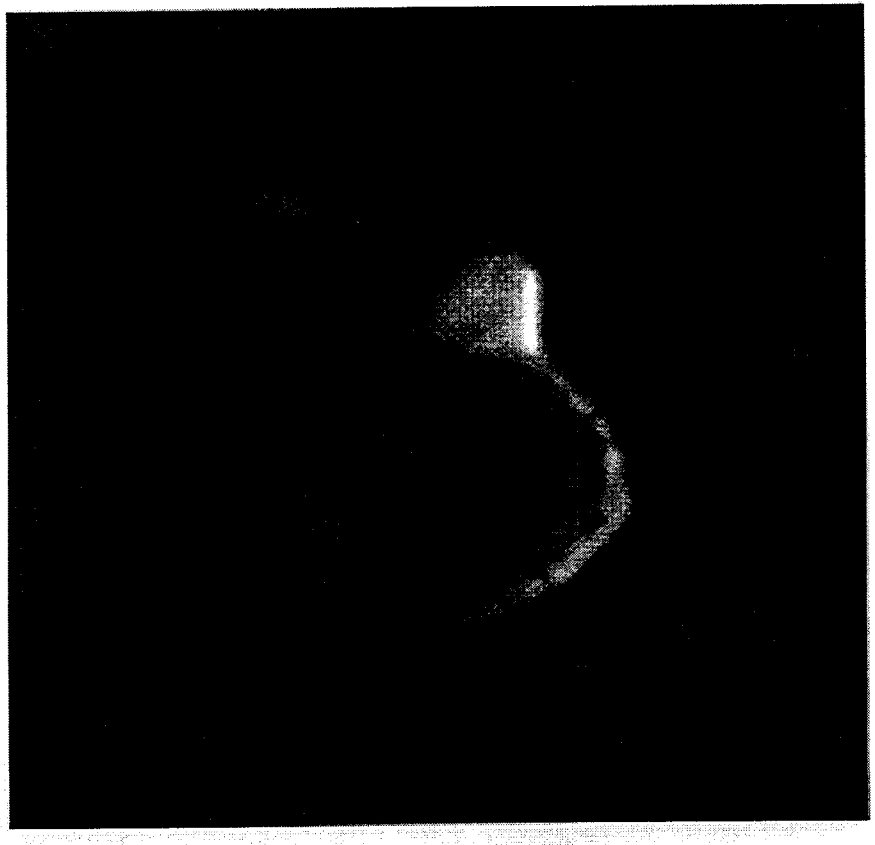
NEAR's Motion Relative to a Fixed Sun–Eros Line



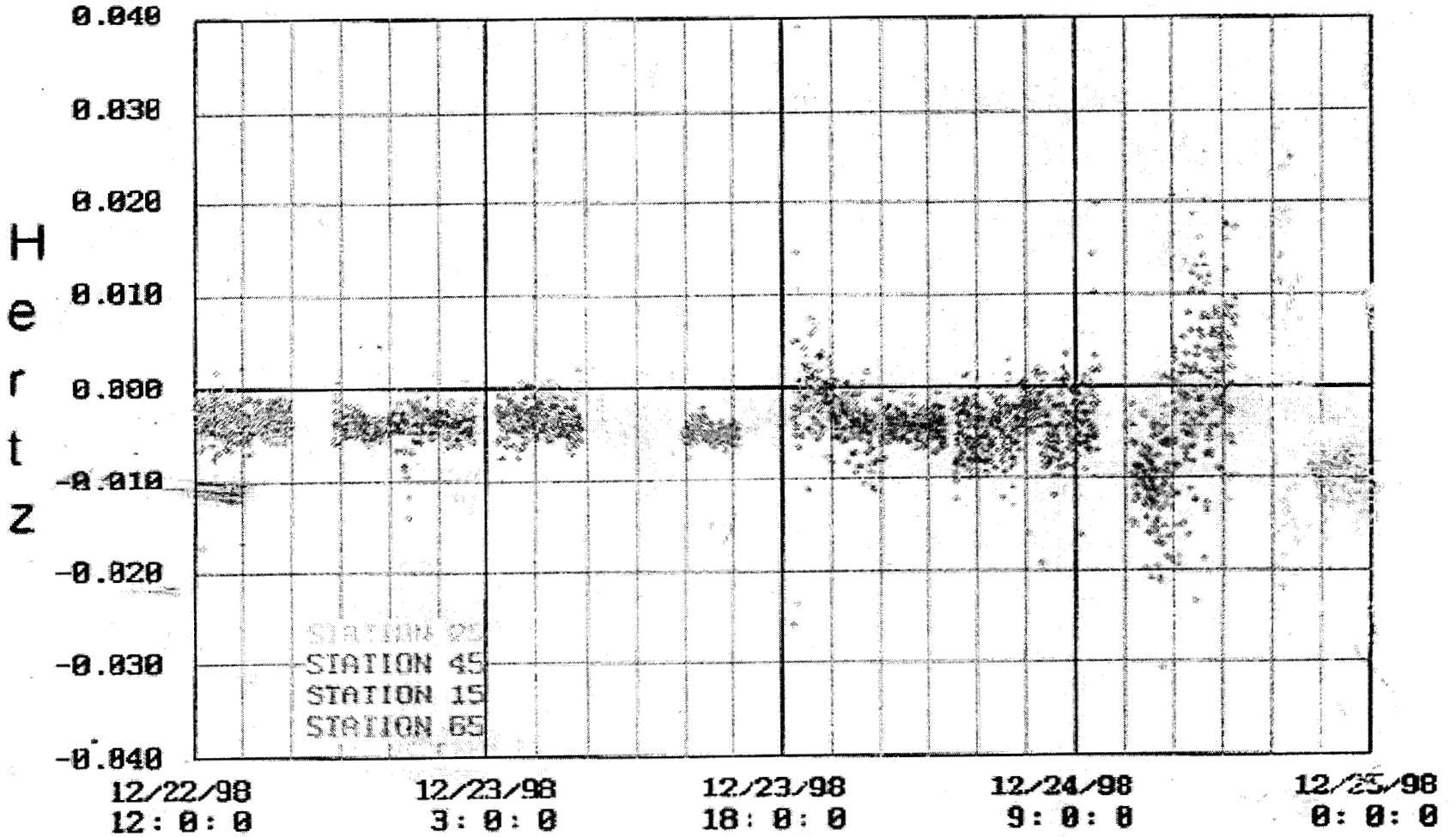
EROS IMAGE

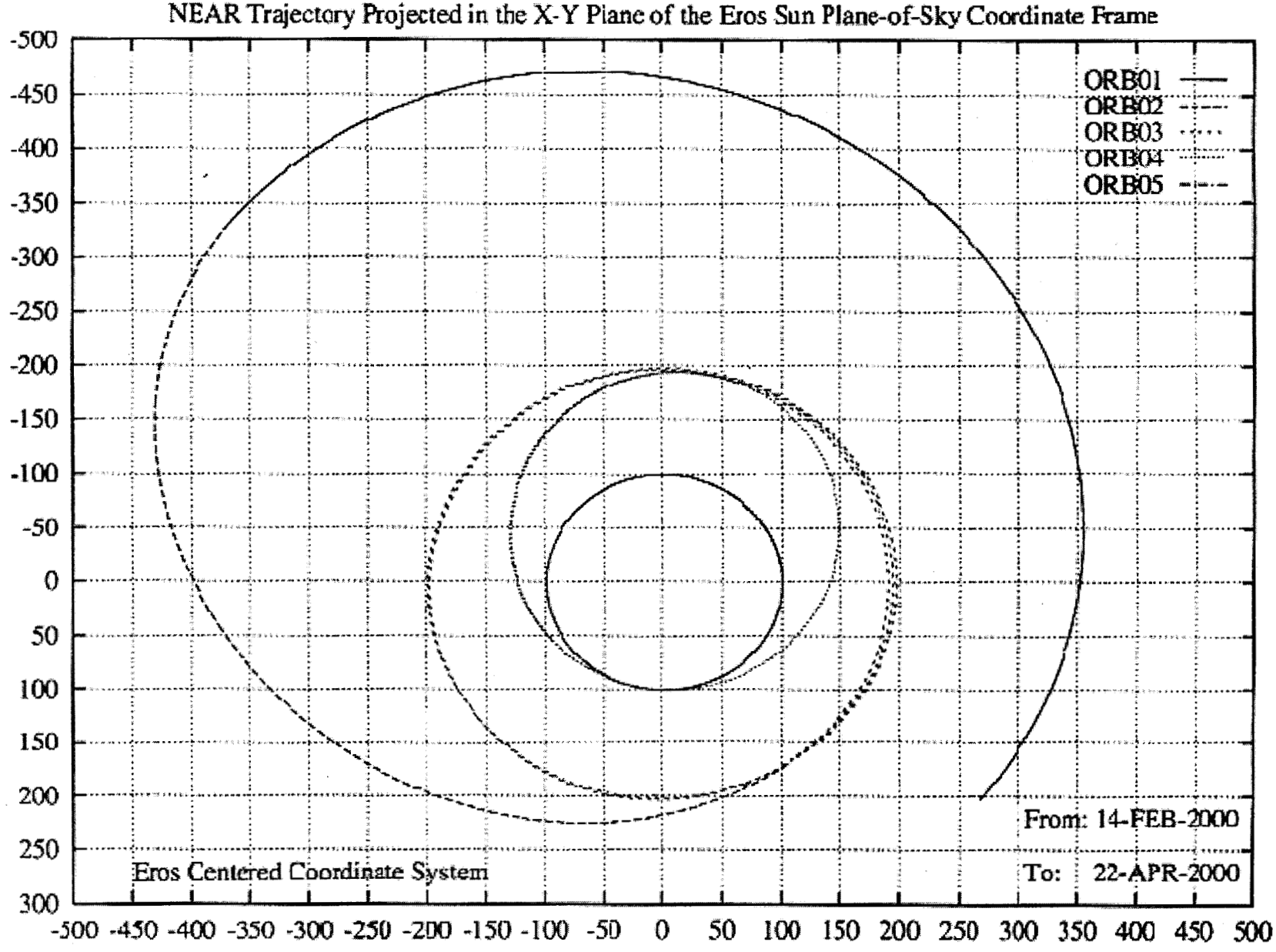
Simulated Image



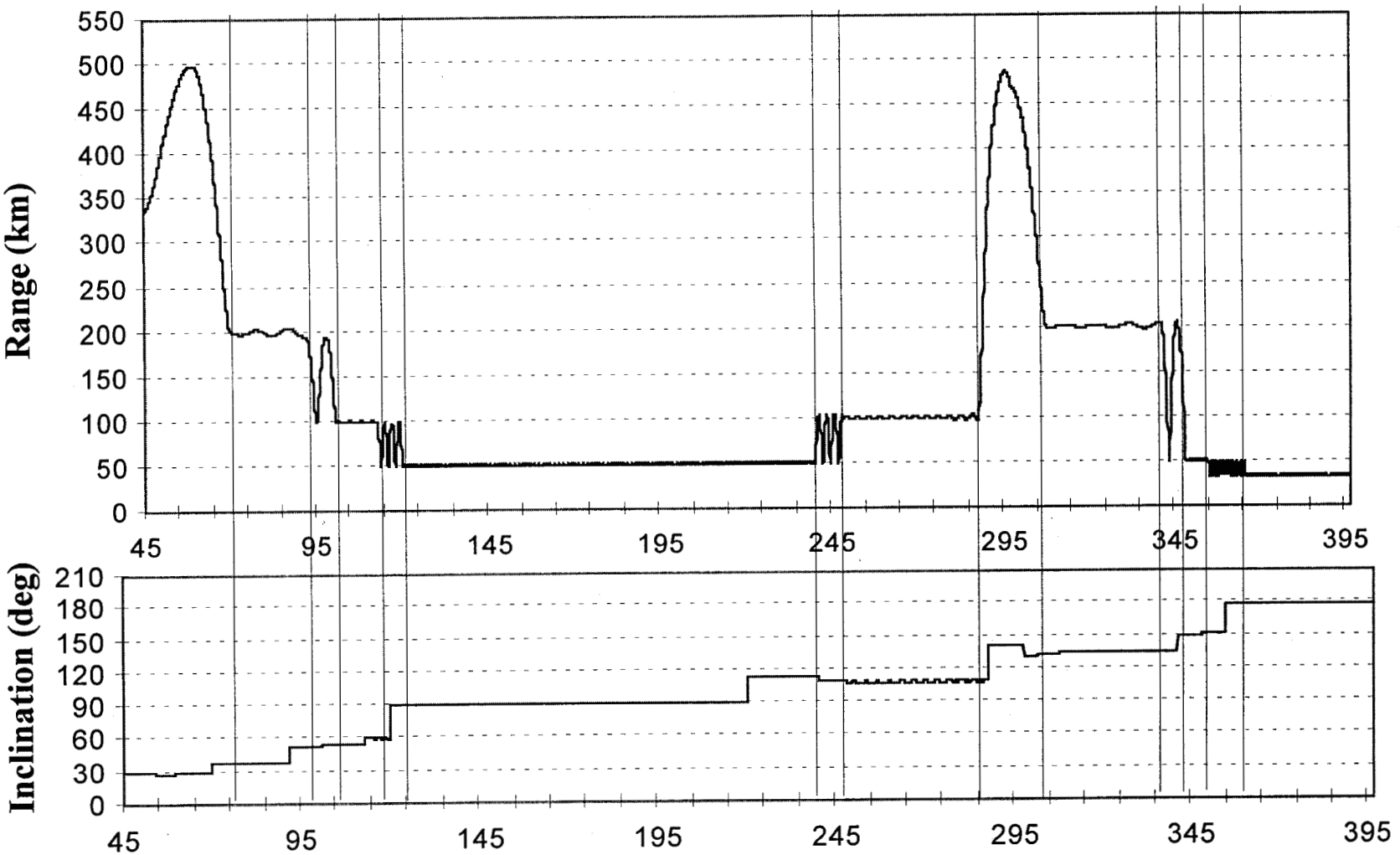
Actual Image

NEAR EROS FLYBY DOPPLER RESIDUALS
60 SEC DATA

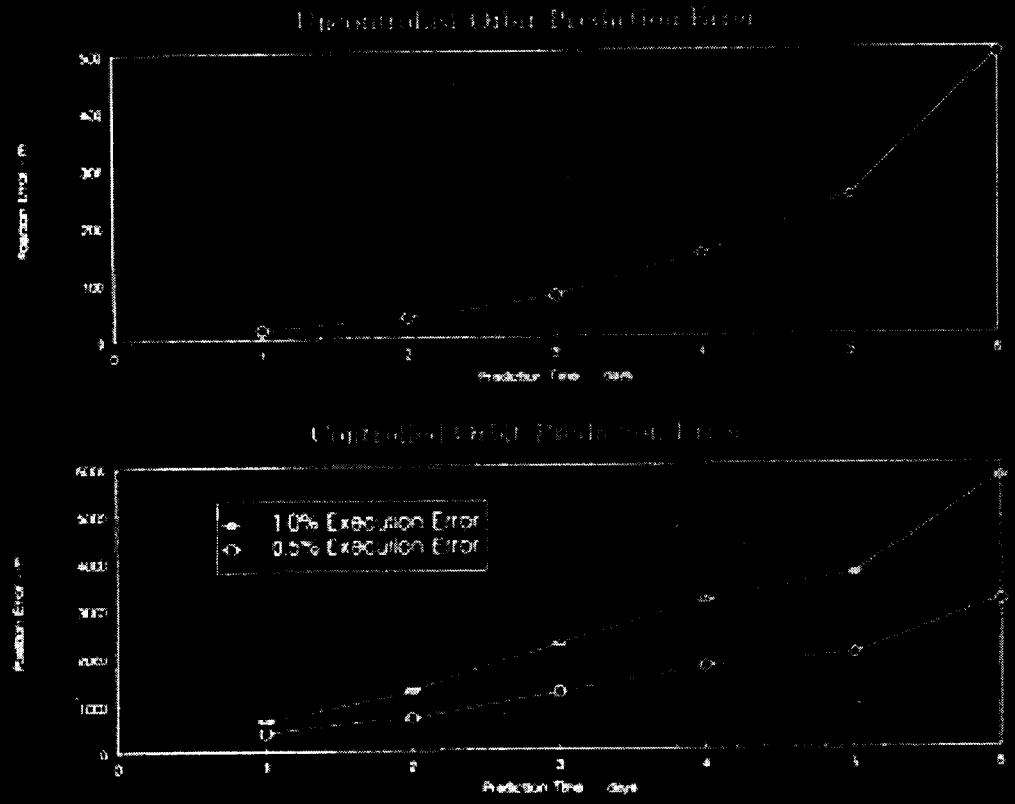



NEAR Trajectory Projected in the X-Y Plane of the Eros Sun Plane-of-Sky Coordinate Frame
ORB01
ORB02
ORB03
ORB04
ORB05
From: 14-FEB-2000
To: 22-APR-2000
Eros Centered Coordinate System
-500 -450 -400 -350 -300 -250 -200 -150 -100 -50 0 50 100 150 200 250 300 350 400 450 500
-500 -450 -400 -350 -300 -250 -200 -150 -100 -50 0 50 100 150 200 250 300

Spacecraft Trajectory Profile at Eros (4-7-99 version)



Mapping Orbit Prediction Errors



Orbit Phase Initial Reconnaissance

Eros Physical Parameters

Parameter	Accuracy(1 sigma)	
	Apriori	Estimated
Attitude	10 deg	0.05 deg
Spin	1 deg/s	9.5×10^{-6} deg/s
Gravity (μ)	100%	0.95%
Gravity (J_2)	0.1	3.9×10^{-2}
Inertia Tensor (I_{xx})	0.1	7.6×10^{-2}
Landmark Location	400 m	130 m

† Data consisted of 3 days of Doppler and Optical Imaging of Landmarks

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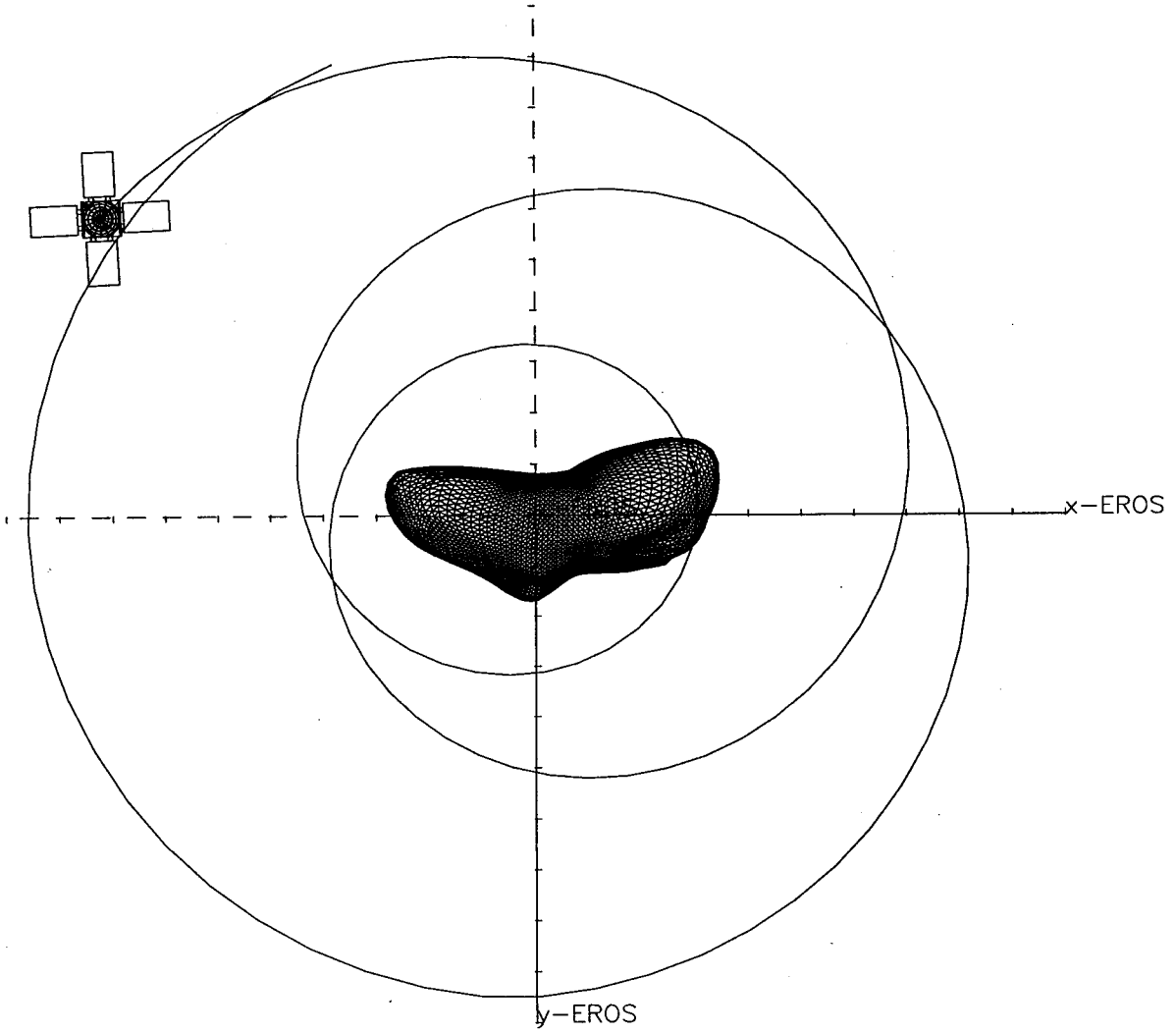
Body-fixed View of a 4th Quadrant (Trailing Edge) Close Flyby Orbit



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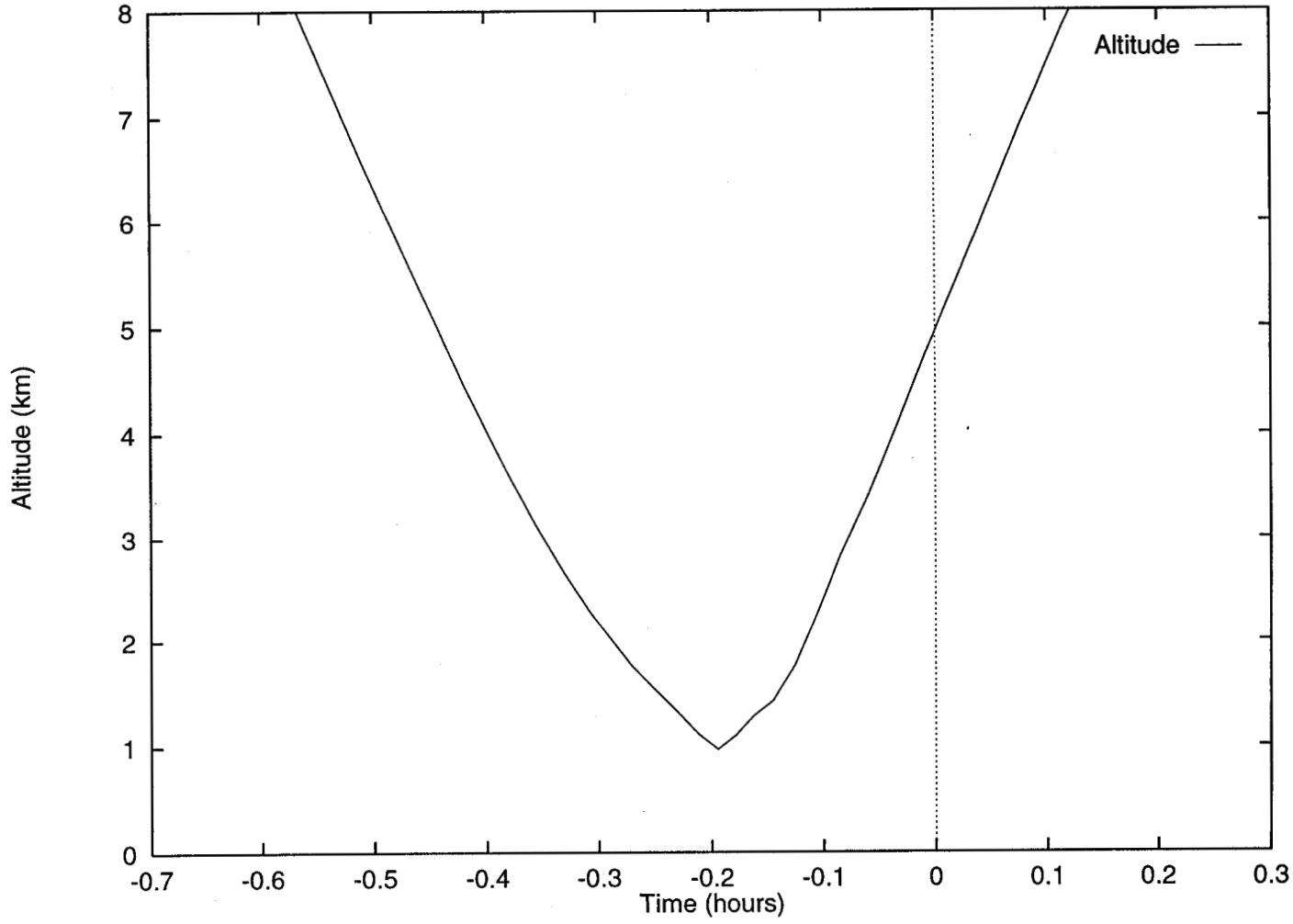
The Altitude Vs Time from Periapsis for 1st Close Flyby (59 X 16 km) Orbit



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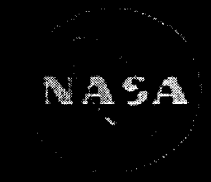
Conclusion

- Navigation for NEAR uses radio metric and optical data types
  - Laser range also available below 100 km alt.
- Unlike planetary orbiter missions, navigation for NEAR depends on rapid estimates of asteroid physical parameters
  - Spin state, gravity field, shape



Eros Physical Parameters Reconstruction

Eros Physical Parameters

Parameter	Accuracy (1-sigma)	
	Apriori	Estimate†
Attitude	10 deg	65 deg
Spin	1 deg/s	5.6×10^{-7} deg/s
Gravity (μ)	100%	0.11%
Gravity (J_2)	0.1	1.2×10^{-3}
Inertia Tensor (I_{xz})	0.1	1.0×10^{-3}
Landmark Location	400 m	9.2 m

† Data consisted of 3 days of Doppler and Optical Imaging of Landmarks

The Shape Model of Eros Determined from NEAR's Flyby on Dec 23, 1998